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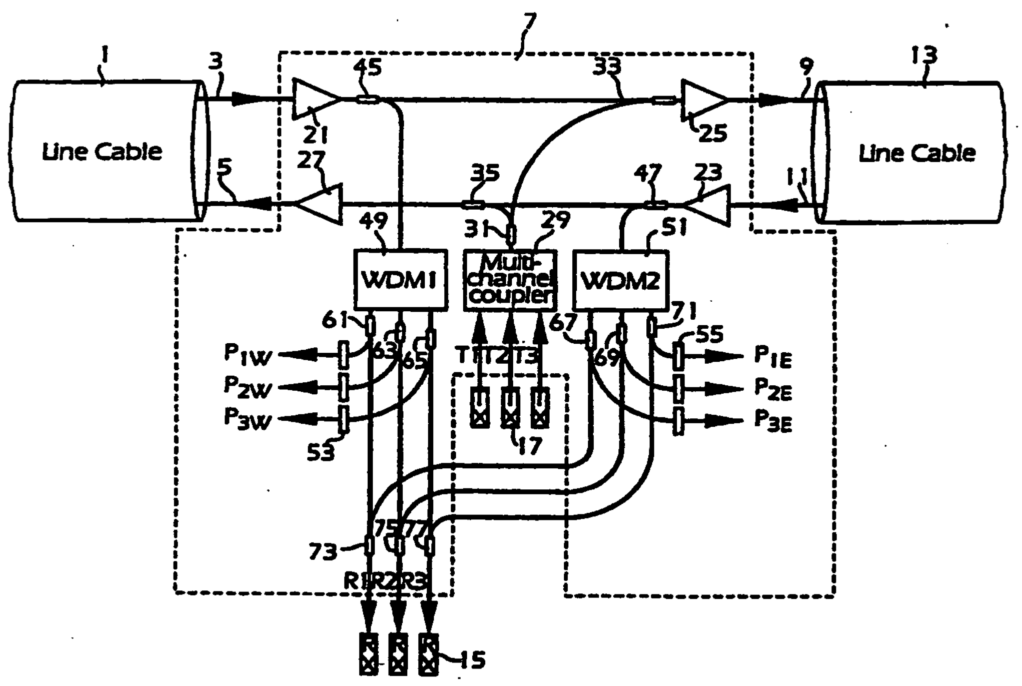
(54) Title: AN ADD AND DROP NODE FOR OPTICAL COMMUNICATION SYSTEMS

(57) Abstract



An add/drop (7) node for an optical fiber network of WDM type has preamplifiers (21, 23) connected to the input fibers (3, 11). Part of the incoming signal power is tapped off by means of drop couplers or splitters (45, 47). The tapped-off power is provided to demultiplexers (49, 51), one demultiplexer being used for each direction, in which WDM information channels are separated from each other. The output signals of the two demultiplexers which comprise the same wavelength interval are combined in combining couplers (73, 75, 77) and then fed to optoelectrical receivers (15), where the information of the dropped channels is converted to electrical signals. In order to monitor and maintain a satisfactory transmission quality of the signal from the node (7), the optical power in each wavelength channel of the multiplexed light signal transmitted in the network is measured, independently for west and east traffic, by adding splitting couplers (61, 63, 65; 67, 69, 71) to the outputs of the demultiplexers (49, 51). These splitting couplers deflect a portion of the signal power to optical power detectors (53), which provide signals informing on the individual power levels. This design gives a node having a minimum number of multiplexers and also the node has a better performance in failure states. WDM information channels to be added in the node from electro-optical transmitters (17) are combined in a multiplexer (29), the resulting signal being split (31) and provided to add couplers (33, 35) to which also the signals incoming to the node are provided.

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AN ADD AND DROP NODE FOR OPTICAL COMMUNICATION SYSTEMS

TECHNICAL FIELD

The present application relates to optical communications systems employing wavelength division multiplexing of optical channels, in particular in self-healing ring architectures, and to an add/

drop node, also called add and drop node, used in such systems.

BACKGROUND

Nowadays, there is an interest in using multichannel, wavelength division multiplexed or WDM systems in order to enhance the transmission capability of existing fiber optical networks, so that channels which previously would have to be transmitted on a plurality of separate fiber pairs now can be forwarded on a single fiber pair. In that way, fiber pairs are released and can be used for increasing the number of transmission channels and thereby the transmission capability of the system or for other network enhancements.

Using optical wavelength division multiplexed channels means that a plurality of serial information signals, i.e. a plurality of serial binary signals, are transmitted on the same optical fiber by first modulating each such a serial signal on a monochromatic light signal, i.e. a light signal having a definite wavelength, and then combining the modulated light signals in an optical coupler or optical multiplexer to a composite light signal, also called WDM light signal, transmitted on the considered optical fiber. The signal primarily modulated on a monochromatic carrier light signal together with the carrier can be called a traffic channel or only a channel, a WDM information channel or simply a WDM channel or wavelength channel.

Optical wavelength multiplexing can be used to construct different optical fiber network solutions, e.g. solutions using point to point links, hubbed structures, etc. Hereinafter the "Flexbus" concept, see the International patent application PCT/SE96/00441, will be used as a typical network structure. All such networks require the possibility to add and drop one or more wavelength channels, see Fig. 1, at selected places of the fiber optical network, these places being called add/drop nodes or add and drop nodes. For the fiber optical WDM network of Fig. 1 having two add/drop nodes, a left line cable 1 comprising two optical fibers 3, 5 for transmission of light signals in both directions are coupled to one side of such an optical add/drop node 7, the other side of the node 7 being connected to the two fibers 9, 11 of a right line cable 13. The node 7 is connected to or contains receivers 15 and transmitters 17 for converting optical signals to electrical signals and vice versa, the electrical signals being transferred to or received from, respectively, other devices, links or networks, not shown. The line cables 1, 13 ending at a node 7 have their other ends connected to other, for example identically constructed nodes 7.

Fig. 2 illustrates a simplified schematic of an add/drop node in a "Flexbus" ring-

type, optical network. Three wavelength channels are illustrated in the examples that follow, although the structure can and shall be extended to serve more channels. The fibers 3, 11 carrying traffic to the node 7 are connected to preamplifiers 21, 23 and the fibers 9, 5 carrying traffic from the node are connected to booster or power amplifiers 25, 27. The respective preamplifiers 21, 23 and the boosters 25, 27 are connected to each other, so that traffic channels can pass through the node 7 in a basically uninterrupted way. The output terminals of the preamplifiers 21, 23 and the input terminals of the power amplifiers are also connected to input ports of optoelectrical receivers 15 and to output ports of electrooptical transmitters 17 respectively through an internal network of couplers and demultiplexers.

Traffic channels T1, ..., T3 originating at the considered node, coming from the transmitters 17, are combined in an optical coupler or optical multiplexer 29, also called a wavelength multiplexer. The combined signal is in another coupler 31 split into two signals having each substantially the same power as the other one and these two equal power signals are injected into the ring paths in both a westerly and easterly direction by means of couplers 33, 35 arranged in the connection line between the output terminal of a preamplifier 21, 23 and the input terminal of a power amplifier 25, 27. In the corresponding way, a proportion of the wavelength multiplex of signals arriving at the node 7 is coupled or tapped from the easterly and westerly directions by couplers 37, 39 also arranged in the connection line between the output terminal of a preamplifier 21, 23 and the input terminal of a power amplifier 25, 27. The tapped-off signals are combined in a coupler 41 prior to being demultiplexed into individual traffic channels R1, ..., R3 by a wavelength division demultiplexer 43, the input terminal of which is thus connected to the coupler 41 and the output terminals of which are connected to input terminals of the optoelectrical receivers 15.

To monitor and maintain a satisfactory transmission quality, it is advantageous to monitor the optical power in each wavelength channel of the WDM light signal or signal multiplex borne on the ring network. The optical power must be measured independently for west and east traffic. The typical mechanism by which this may be accomplished is to use further wavelength division demultiplexers to separate the multiplexed WDM light signal or signal multiplex into its individual wavelength channels and then convert the optical power in each channel to an electrical signal by means of a multiplicity of optical power detectors. This is illustrated in Fig. 2, wherein electrical quantities representing the powers P1W, ..., P3W; P1E, ..., P3E of channels arriving from west and east respectively are derived from further couplers 45, 47 connected in the connection line between the output terminal of a preamplifier 21, 23 and the input terminal of a power amplifier 25, 27, preferably directly at the output terminal of the respective preamplifier. These couplers 45, 47 are connected to input terminals of wavelength division demultiplexers 49, 51, which have their output terminals coupled to the inputs of

associated optoelectrical detectors 53, 55 providing said channel powers or channel strengths.

The prior method has various disadvantages. These include a) the need for the node to include three wavelength division multiplexers, each a costly device requiring thermal stabilisation and supervision and b) that the design includes common failure modes inasmuch that all dropped traffic channels are vulnerable to failures in either the wavelength division demultiplexer 43 connected to the receivers 15 or the west/east signal combination coupler 37, 39 that takes out a proportion of the arriving signal to be combined in the coupler 41 connected to the input terminal of the demultiplexer 43.

In U.S. patent US-A 5,510,917 an optical communication monitoring and control system is disclosed for monitoring traffic in optical, bidirectional communication networks. In each node the signal in the fibers is tapped and the power of the signal is measured. Then one wavelength detector is used for each direction. In addition, another demultiplexer is used for separating the wavelengths before the respective signals reach the receivers. This disclosure corresponds in some detail to the prior art node of Fig. 2 discussed above.

The published International patent application WO-A1 97/01907 discloses a selfhealing optical network. Power levels are monitored. U.S. patent US-A 5,335,104 discloses a method of detecting breaks in an optical WDM network. It is made by measuring the power of a received signal and comparing it to a reference voltage. An add/drop node for a bidirectional optical network is also disclosed in the published International patent application WO-A1 96/19884. The signals in a primary ring and a secondary rings are monitored at each node for detecting breaks. U.S. patent US-A 5,548,431 discloses a node for a bidirectional optical network having a ring structure. In each node two wavelength modems are provided.

SUMMARY

It is an object of the invention to provide an add/drop node intended to be used in an optical fiber network and having a structure that is reliable and non-costly and in particular contains a minimum number of optical demultiplexers.

It is another object of the invention to provide an add/drop node that is particularly suited to be used in a network having a self-healing mechanism, such as the "Flexbus" concept.

Thus in an add/drop node in an optical communication network of for example ring-type using wavelength division multiplexing the light signal is tapped and demultiplexed by one optical demultiplexer, also denoted WDM-unit, per direction, so that the power for each channel and direction can be measured. Thereafter the two compon nts of each channel are combined for providing an output signal, that c rresponds to the input signal, consisting of an arbitrary number of wavelengths. In such a design nly two WDM-units (one per direction) is required in each node in the network instead of the three WDM-

units conventionally being used. In addition, a higher resistance to failures or disturbances in the network is obtained.

The advantages for these improvements are hence that a) one WDM unit has been eliminated, yet the same functionality of traffic demultiplexing and signal monitoring has been retained; b) the common failure modes in the previous scheme affecting all received traffic are eliminated. If one WDM-unit should fail, the self-healing mechanism of the "Flexbus" concept can be used to ensure that all traffic is received from the direction served by the WDM-unit which is still operational and that traffic from the direction served by the failed unit is suppressed. Satisfactory traffic reception is then maintained by the remaining WDM-unit; and c) the scheme is more amenable to in-service maintenance, restoration, and upgrades, since one WDM-unit can support the received traffic during the replacement of the second WDM-unit.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods, processes, instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

While the novel features of the invention are set forth with particularly in the appended claims, a complete understanding of the invention, both as to organization and content, and of the above and other features thereof may be gained from and the invention will be better appreciated from a consideration of the following detailed description of non-limiting embodiments presented hereinbelow with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustrating a prior art optical fiber network having add/drop nodes,

Fig. 2 is a schematic illustrating the structure of a prior art add/drop node having three WDM-units, and

Fig. 3 is a schematic illustrating the structure of an add/drop node having two WDM-units.

DETAILED DESCRIPTION

In Fig. 3 a schematic of an add/drop node 7 for an optical network is illustrated, the network for example being the kind illustrated in Fig. 1. The add/drop node 7 of Fig. 3 has in some substantial parts a structure identical to that of the prior art node of Fig. 2 and the same reference numbers will be used for identical or similar items or elements. The network fibers are assumed to carry three wavelength channels but of course more channels can be used. Optical fibers 3, 11 carrying light signals to the node 7 are connected to the input terminals of preamplifiers 21, 23. The fibers 9, 5 carrying information signals in a direction away from the node are connected to the output

terminals of booster or power amplifiers 25, 27. The respective preamplifiers 21, 23 have their output terminals connected to the input terminals of the power amplifiers 25, 27, so that traffic channels can pass from an input fiber 3, 5 through the node 7 to the respective output fiber 9, 11 in a basically uninterrupted way.

Traffic channels entering the ring at the node 7 are injected in the wavelength multiplexed light signal passing through the node by means of the same arrangement as in the prior art node of Fig. 2. Thus, traffic channels T1, ..., T3 to be combined with the information flow, i.e. other traffic channels transmitted in the network and originating at the node 7, are converted to optical signals of the appropriate wavelength intervals in transmitters 17. These optical signals having different wavelengths are combined in an optical coupler or wavelength or optical multiplexer 29 having its input terminals connected to the output terminals of the transmitters 17. The combined signal is, in a coupler 31 connected to the output terminal of the wavelength multiplexer 29, split into two signals having each a power that is substantially equal that of the other one. These two signals having substantially equal power levels are combined with the traffic flowing in both directions through the node 7 by means of couplers 33, 35 arranged in the connection line between the output terminal of a preamplifier 21, 23 and the input terminal of a power amplifier 25, 27, these couplers 33, 35 having their output terminals directly coupled to the input terminals of the respective power amplifier 25, 27.

However, the channel drop mechanism of the node 7 of Fig. 3 differs from that of Fig. 2. Hence, the wavelength division multiplexer 43 and its associated couplers 37, 39, 41 are eliminated. Like the prior art and in particular its elements for power monitoring, a proportion of the WDM-light signal or wavelength multiplex of signals arriving at the node 7 is coupled from the easterly and westerly directions by drop couplers 45, 47 connected in the connection line between the output terminal of a preamplifier 21, 23 and the input terminal of the associated power amplifier 25, 27, these drop couplers 45, 47 being connected directly to the output terminal of the respective preamplifier 21, 23. The drop couplers 45, 47 are like the prior art connected to wavelength division demultiplexers or WDM-units 49, 51, which on their output terminals provide light signals each carrying only one wavelength interval and one information channel. These output terminals are coupled to the input terminals of associated optical power detectors 53, 55 thus providing on their output terminals electrical signals representing the channel powers or strengths P1W, ..., P3W; P1E, ..., P3E of the channels which are transmitted in the network and which arrive from west and east respectively. These channel strengths or power levels of the individual channels are required in order to monitor and maintain a satisfactory transmission quality of the signal multiplex propagating in the ring network.

Each traffic channel from the west, that has been demultiplexed by the demultiplexer 49, is then combined with the corresponding channel from the east, which thus is carried by light in the same wavelength interval and has been demultiplexed by the

demultiplexer 51. Therefor, first the signals on each of the output terminals of each demultiplexer 49, 51 is split into two signals of for example substantially equal power levels by means of couplers 61, 63, 65; 67, 69, 71 which each have their input terminal connected to an output terminal of the demultiplexer 49, 51 and one output terminal connected to the input terminal of an optical power detector 53. The other output terminal is coupled to a combining coupler 73, 75, 77, one such combining coupler being provided for each and every traffic channel. A combining coupler 73, 75, 77 has thus one of its two input terminals connected to one splitting coupler 61, 63, 65 for traffic arriving from the west and one splitting coupler 67, 69, 71 for traffic arriving from the east. The output terminals of the combining couplers 73, 75, 77 hence carry the combined set of signals which constitute the channels R1, ..., R3 to be received in the node 7 and these terminals are coupled to the input terminals of optoelectrical receivers 15. There, the received light signals are demodulated and converted to electrical signals for extracting the information therein and possibly forwarding it to a user or another network.

Thus an add/drop node is provided having the same functionality as a conventional add/drop node but comprising only two WDM-units and instead using an additional number of simple couplers for equal power splitting and for combining signals.

While specific embodiments of the invention have been illustrated and described herein, it is realized that numerous additional advantages, modifications and changes will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within a true spirit and scope of the invention.

CLAIMS

1. An add/drop node for an optical fiber network, the node being adapted to be connected to a first optical fiber carrying a WDM light signal comprising a plurality of WDM information channels to the node and to a second optical fiber carrying a WDM light signal comprising a plurality of WDM information channels from the node, the node being arranged to take out or tap in a drop coupler a proportion of the light signal incoming on the first fiber, the signal proportion being transmitted to a wavelength demultiplexer, in which wavelength intervals are separated from each other and which provides a plurality of light signals, one light signal on each of output terminals of the wavelength demultiplexer and each signal carrying only one information channel, **characterized by** splitting couplers, each of which is connected to one of the output terminals of the wavelength demultiplexer and has one output terminal connected to an optical power detector, one detector for each splitting coupler, another output terminal of a splitting coupler providing a light signal to an optoelectrical receiver.

2. An add/drop node according to claim 1, **characterized** in that the node is adapted to be connected to two first optical fibers carrying each a WDM light signal, these WDM light signals propagating in opposite directions and each comprising a plurality of WDM information channels incoming to the node and to two corresponding second optical fibers each carrying a WDM light signal, the WDM light signals propagating in opposite directions, pairs being formed of one second fiber and one first fiber, the fibers of a pair carrying light signals having the same directions, and the WDM light signals on each second optical fiber comprising a plurality of WDM information channels going out from the node, one drop coupler being arranged for each pair and one demultiplexer connected to each drop coupler, splitting couplers and optical power detectors being connected to the wavelength demultiplexers, a combining coupler having input terminals, one of which is connected to a second output terminal of a first splitting coupler and another input terminal of which is connected to a second output terminal of a corresponding, different second splitting coupler which has an input terminal coupled to the demultiplexer, to which the first splitting coupler is not connected.

3. An optical fiber network comprising pieces of optical fibers joined at nodes, **characterized** by an add/drop node according to one of claims 1 - 2, the add/drop node being connected to at least one optical fiber of the network carrying light in a direction to the add/drop node and at least one optical fiber of the network carrying light in a direction away from the add/drop node.

4. An optical fiber network according to claim 3, **characterized** in that the add/drop node is connected to two optical fibers of the network carrying light signals going in a direction to the add/drop node and to two optical fibers of the network carrying lights signals going in a direction away from the add/drop node.

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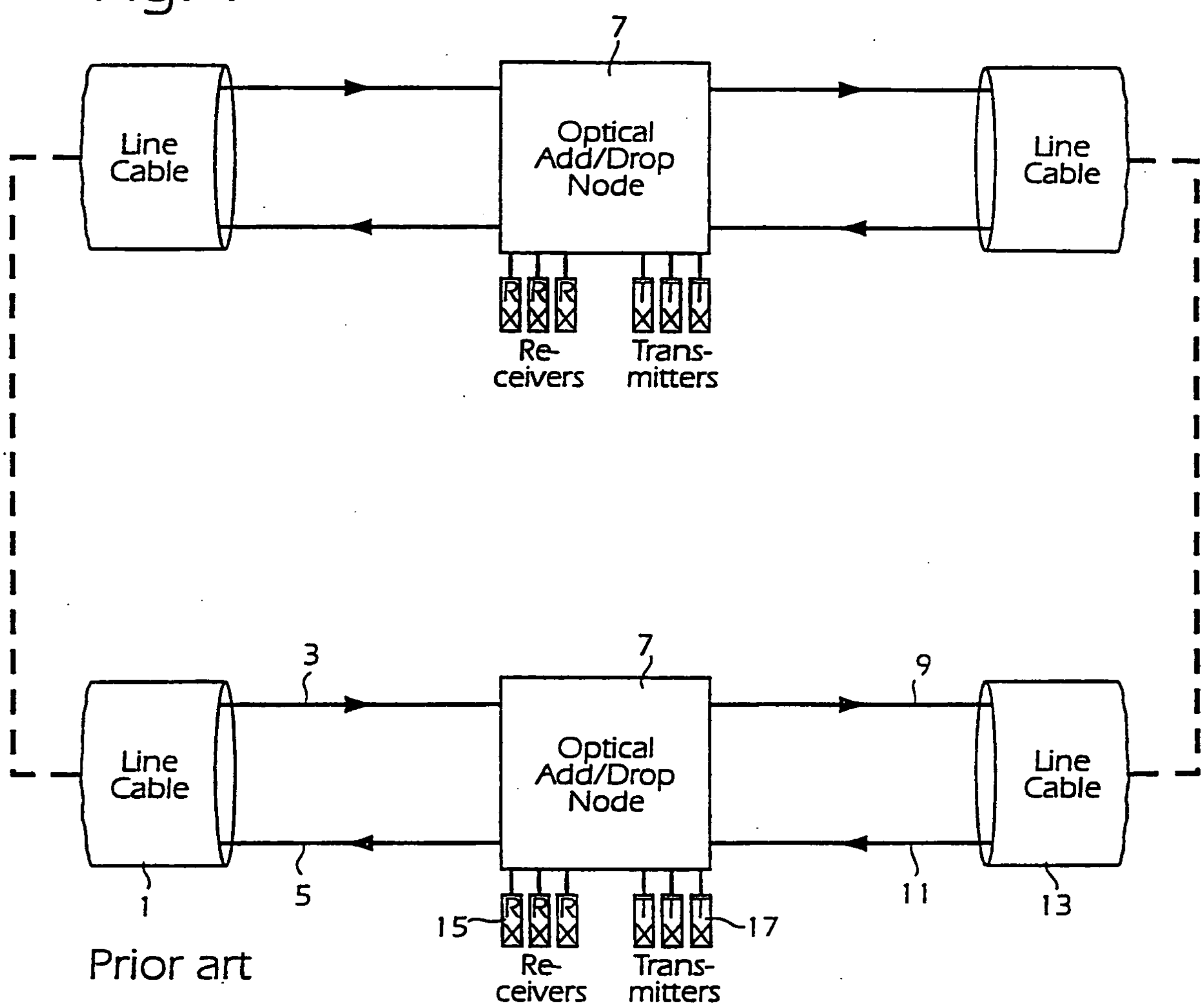
Fig. 1



Prior art

Fig. 2

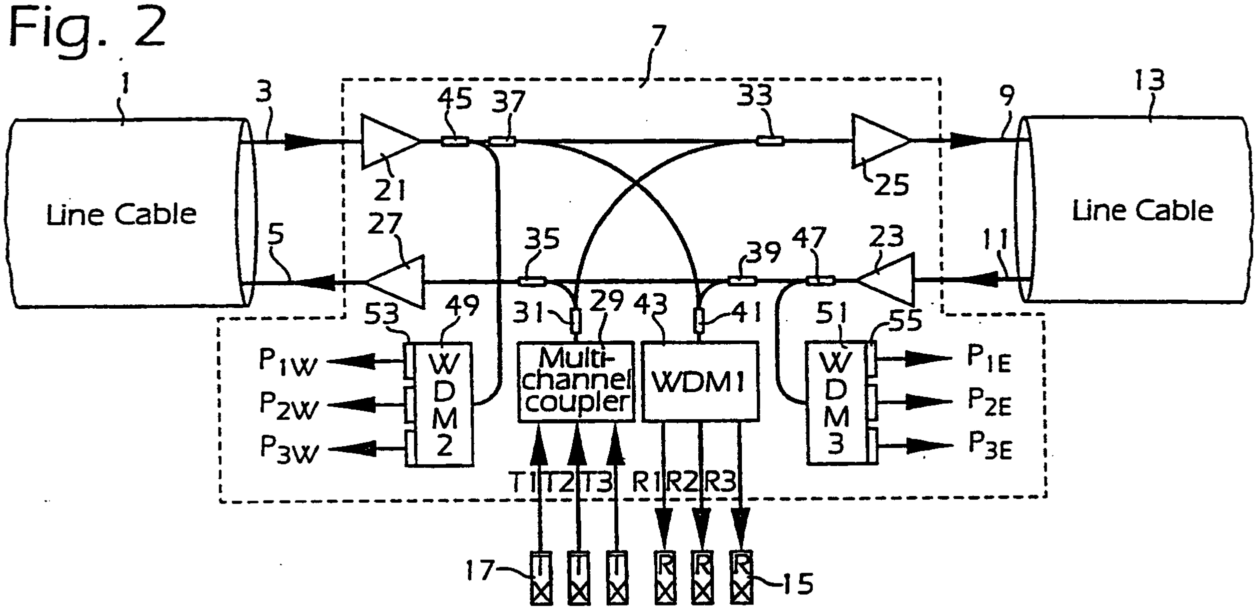


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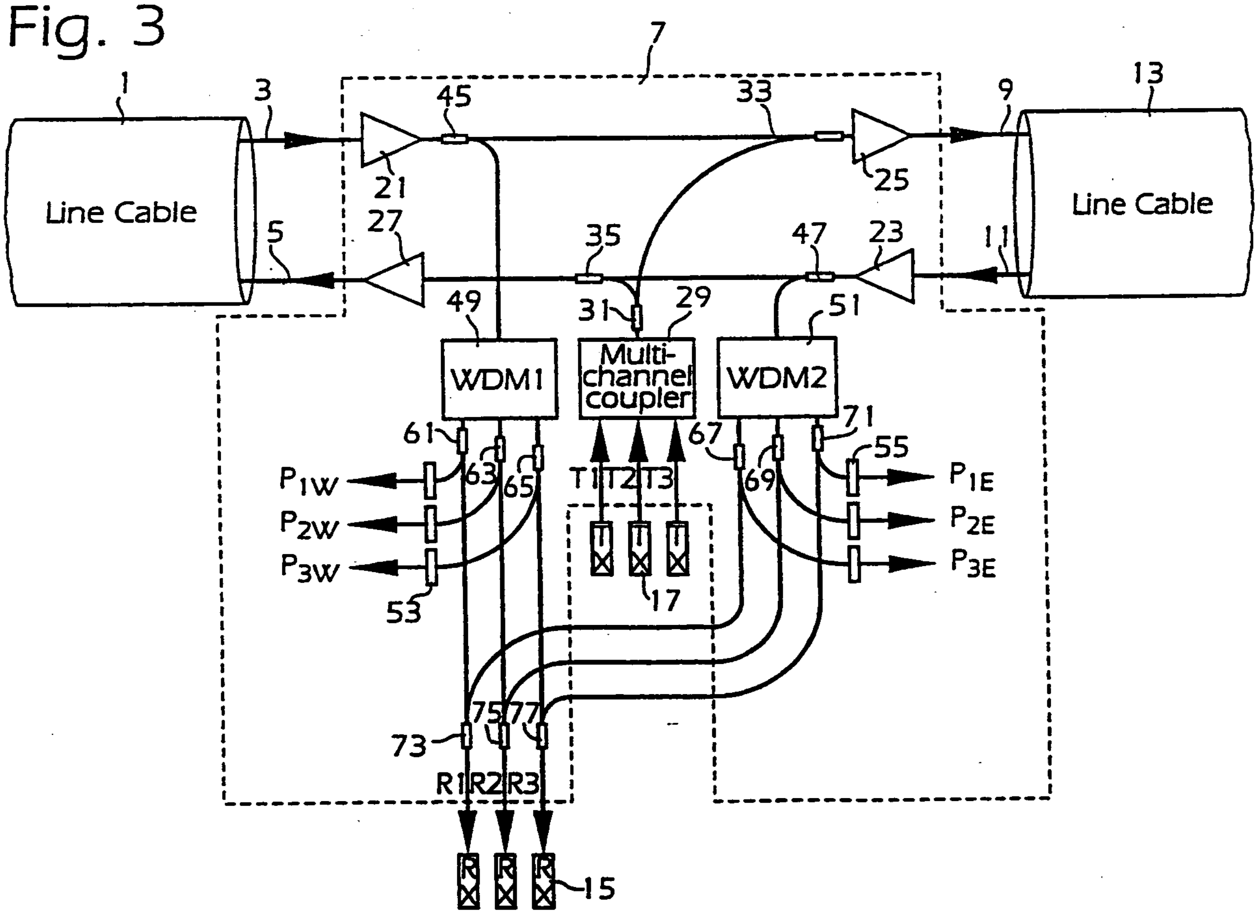
Fig. 3



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